

Supporting Army readiness through a robust digital additive manufacturing supply chain



Project Call Industry Brief

Ashley Totin – NCDMM

Jennifer Coyne - The Barnes Global Advisors

Nat Frampton – LECS Energy

2-Feb-2022

Problem: How repeatable & predictable is AM? Confidence in process repeatability is key to widespread AM adoption

Opportunity: The AMNOW program produced significant digital thread data that can be used to analyze repeatability and predictability of AM.

AMNOW Challenge Objectives:

- 1) Increase visibility to the power of using digital thread data to discover flaws and trends in AM parts
- 2) Stimulate development and discussion of artificial intelligence and data analytics algorithms for finding anomalies in digital thread data sets within the AM community

Overview:

- Phase 1: Access over 36 AM builds in 316L and associated post-processing data to create digital thread insights, visualize data, apply artificial intelligence algorithms, predict properties, find anomalies, or changes.
- Phase 2: Based on findings, work with parts producers to optimize their last 2 builds.
- Prize:
 - ASOW-154 Initial Phase (up to 5 awards with no funding, Up to \$45k America Makes cost share, based on evaluation panel score)
 - ASOW-155 Final Phase (up to 3 awards @ \$50k/award or \$50k AM cost share)

Key Dates

Industry Briefing	February 2, 2022
RFP Released	February 7, 2022
RFP Reply Due	February 21, 2022
Downselected teams' presentations	February 25, 2022
Phase 1 participants announced	February 28, 2022
Project awarded and NDA signed	March 2, 2022
Data access granted via SharePoint, pending award acceptance	March 4, 2022
Phase 1 presentations	April 30, 2022
Phase 1 winners announced	May 18, 2022
Phase 2 presentations	Week of Aug 14, 2022
Phase 2 final report	August 31, 2022

Technical – Contained in 15min Presentation for the Evaluation Board

- Addressing ASOW-154 and ASOW-155
- Draft Execution Plan and Schedule
- Overview of approach and proposed software or tools, including description of off-the-shelf or proprietary tools.
- What They Plan to Demonstrate
- What Benefit They Could Provide for Final 2 Builds

Programmatic

- Participating Organizations and DD2345 Registration
- Identification of Single Person from Team to Access SharePoint and Download Data
- Willingness to sign NDA and certify deletion of data at the end of program
- Willingness to present results at an America Makes or NCDMM Sponsored event in 2022
- Non-competitor or common ownership, ATI Specialty Metals, Penn United, Innovative 3D Manufacturing

Cost – Not Required

Registrants to the Industry Brief will Receive Email with Link to RFP

- Build Layout – STEP or STL
 - Penn State – Build #1 – Elbows & Coupons
 - Production Representative – Builds 2, 3, 7-12 – Elbows & Coupons
 - Simulated Operational Qualification – Builds 4-6 - Coupons Only

- Print – LIMS JSON – Next Slide

- Powder, Post-Process and Property Data

Type	Format	Template	Notes
Powder Certs	Excel	AMNOW-913	
Thermal Processing	Excel	AMNOW-978	
Radiographic Inspection	Excel - Guide	AMNOW-979	Links Radiographs to Part
	Radiographs	DICONDE	
Coupon Testing	Excel	AMNOW-990	May Not Have Build 1 Results
Microstructure	JPG / PNG	none	

Header Information

ASOW153-LPBF - 12/3/2021 2:51:46 PM

Amip Version - 1.22

Operations Reports

- AMNOW Document # - 931
- AMNOW Part # - 9
- Build # - 7
- Build ASOW - 153
- Build ID - 12/436
- Device ID - LIMS-DEVICE-3
- Edge Device Version - 4.0.22027.0
- End Time-2021-12-06 02:33:25 AM
- Group # - APDP-2
- Job Uuid - 00000000-0000-0000-0000-000000000000
- Latitude - 40.86063
- Longitude - -74.45232
- Part Builder Name - Penn United Technologies
- Part Builder Short Name - PUT
- Part Name - ASOW153-LPBF
- Part Uuid - 00000000-0000-0000-0000-000000000000
- Start Time-2021-12-03 02:51:46 PM

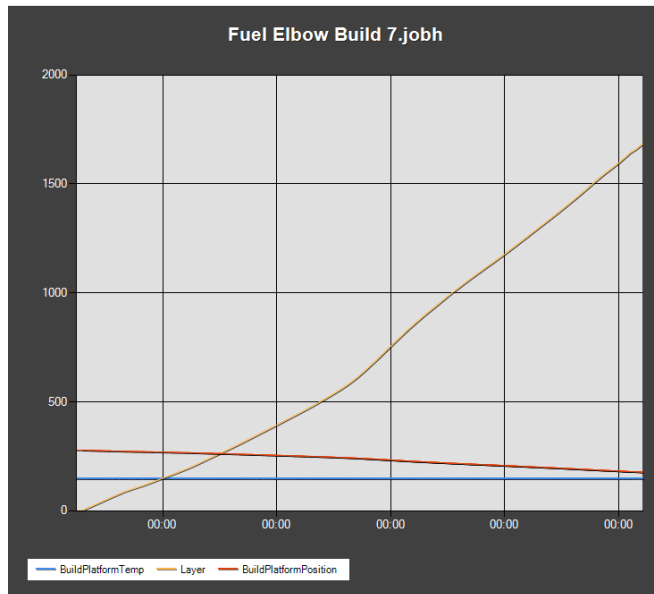
65 KPIs

Step1:Printing

- Address -
- BuildBoxSerialNumber -
- BuildPlatformPosition - (MILLIMETER) --- [4208 Items]
- BuildPlatformSpeed - (MILLIMETER/SECOND) --- [1278 Items]
- BuildPlatformTemp - (CELSIUS) --- [18030 Items]
- CalibrationDate -
- ChamberAbsoluteHumidity - (PERCENT)
- ChamberO2Con - 0.0 (PERCENT)
- ChamberO2ConBottom - (PERCENT)
- ChamberO2ConTop - (PERCENT) --- [20518 Items]
- ChamberTemperature - (CELSIUS)
- CollectorPlatformPosition - (MILLIMETER)
- CollectorPlatformSpeed - (MILLIMETER/SECOND)
- CollimatorTemperature - (CELSIUS)
- ControlSoftwareRev -
- DispenserFillLevel - (PERCENT)
- DispenserPosition - (MILLIMETER)
- DispenserSpeed - (MILLIMETER/SECOND)
- DosageFactor - (PERCENT)
- EndTime - 2021-12-06 02:33:25 AM
- EnvironmentHumidity - (PERCENT)
- EnvironmentTemp - (CELSIUS) --- [15858 Items]
- FilterO2Con - (PERCENT)
- FilterPressure - 0.0 (PSI)
- FiltrationConfig -
- FiltrationHistory -
- GasFlowConfig -
- GasFlowHistory -
- InertGasFlowRate - Ar (LITER/MINUTE)
- InertGasType - Ar
- InfillDensity - (PERCENT)
- InfillOverlapPercent - (PERCENT)
- InfillPattern -
- JobKWH - 0 (WATT_HOURS)
- LaserPower - (WATT)
- LaserTemp - (CELSIUS)
- Layer - --- [1683 Items]
- LayerThickness - (MICROMETER)
- MachineClass -
- Make -
- Material - --- [2 Items]
- Model -
- Notes -
- OpticalTrainConfig -
- OpticalTrainHistory -
- ParameterDataSet -
- PartFile -
- ProcessGasFlowBottom - (LITER/MINUTE)
- ProcessGasFlowTop - (LITER/MINUTE)
- ProcessMonitor -
- RecoaterAxisTorque - (NEWTON-METER) --- [65234 Items]
- RecoaterMechConfig -
- RecoaterMechHistory -
- RecoaterPosition - (MILLIMETER) --- [5048 Items]
- RecoaterSpeed - (MILLIMETER/SECOND) --- [4102 Items]
- ScanHeadTemperature - (CELSIUS)
- SerialNumber -
- ShopHumidity - (PERCENT) --- [845 Items]
- ShopTemperature - (CELSIUS) --- [15858 Items]
- StartTime - 2021-12-03 02:51:46 PM
- Tip -
- TurbineAxisTorque - (NEWTON-METER)
- TurbinePosition - (MILLIMETER)
- TurbineSpeed - (MILLIMETER/SECOND)
- Utilization - (PERCENT) --- [170937 Items]

Single Report File

- JSON Format
- Data Array contains simple arrays
- Includes Type and Units



JSON

```
{
  "Name": "LayerHeight",
  "EquipmentType": "JobHistory",
  "ID": null,
  "Value": "",
  "Units": "MILLIMETER",
  "Scale": 0.0,
  "Offset": 0.0,
  "DataType": "double",
  "Action": "",
  "SeriesData": [
    {
      "ValueTime": "2022-01-29 08:51:26 PM",
      "Value": "0"
    },
    {
      "ValueTime": "2022-01-29 08:54:23 PM",
      "Value": "0.05"
    },
    {
      "ValueTime": "2022-01-29 08:55:09 PM",
      "Value": "0.2"
    },
    {
      "ValueTime": "2022-01-29 09:01:06 PM",
      "Value": "0.1999999999999999"
    },
    {
      "ValueTime": "2022-01-29 09:01:16 PM",
      "Value": "0.2"
    }
  ]
}
```

Solution Builder®

BuildPlatformTemp - (CELSIUS) --- [18030 Items]
2021-12-03 02:51:46 PM - 149.899993896484
2021-12-03 02:51:52 PM - 149.966995239258
2021-12-03 02:52:05 PM - 149.932998657227
2021-12-03 02:52:15 PM - 149.966995239258
2021-12-03 02:52:25 PM - 149.899993896484
2021-12-03 02:53:05 PM - 149.867004394531
2021-12-03 02:53:15 PM - 149.932998657227
2021-12-03 02:53:25 PM - 149.899993896484
2021-12-03 02:54:05 PM - 149.932998657227
2021-12-03 02:54:15 PM - 149.899993896484
2021-12-03 02:54:25 PM - 149.966995239258
2021-12-03 02:54:35 PM - 149.932998657227
2021-12-03 02:54:45 PM - 149.966995239258
2021-12-03 02:54:55 PM - 149.899993896484
2021-12-03 02:55:05 PM - 150
2021-12-03 02:55:15 PM - 149.932998657227
2021-12-03 02:55:25 PM - 149.966995239258
2021-12-03 02:55:35 PM - 150
2021-12-03 02:55:45 PM - 149.932998657227
2021-12-03 02:55:55 PM - 150
2021-12-03 02:56:05 PM - 149.932998657227

Thermal Treatment (AMNOW-978) – Showing Common Header



Data Item	Field	Units	Value	Time	Vac/Press (Paschals)	Velocity (m/s)	T/C #1 (deg C)	T/C #2 (deg C)	T/C #3 (deg C)	T/C #4 (deg C)	T/C #5 (deg C)	T/C #6 (deg C)	T/C #7 (deg C)	T/C #8 (deg C)	T/C #9 (deg C)	T/C #10 (deg C)
AMNOW Document Number	string		978													
Part Builder Name	string															
Part Builder Short Name	string															
Build Identification	string															
Build Start Date and Time	string	YYYY-MM-DDThh:mm														
Build ASOW #	number															
Group #	number															
Build #	number															
AMNOW Part #	number															
Individual Part or Coupon Numbers	number															
Material	string															
Material Specification (e.g. AMS 7030)	string															
Thermal Processor Name	string															
Thermal Processor Facility	string															
Thermal Processor Contract	string															
Equipment Number	string															
Thermal Profile Report #	string															
Thermal Process Type	string															
Thermal Process Specification	string															
Thermal Process Sub-Specification	string															
Equipment Run Number	string															
Heat Treat Fixture Identification	string															
Atmosphere Type	string															
Atmosphere Velocity	number	meters/s														
Quenchant Type	string															
Quenchant Velocity	number	meters/s														
Set Temperature #1	C	C														
Set Temperature #2	C	C														
Set Temperature #3	C	C														
Set Temperature #4	C	C														
Set Temperature #5	C	C														
Set Pressure/Vacuum #1	number	Paschals														

Supplier (ATI, Penn United, Innovative 3D Manufacturing)

Build Files (3 STEP & 3 STL per Supplier)

Penn State – Build #1 – Elbows & Coupons
Production Representative – Builds 2, 3, 7-12 – Elbows & Coupons
Simulated Operational Qualification – Coupons Only

Build 1 (XXXX is Build ID)

Feedstock (XXXX_913.xls) – 1 file
Print (XXXX.amrp) – LIMS Times Series – 1 file
Thermal Processing (XXXX_978.xls) – 1 (HIP) file
Radiographic Inspection Guide (XXXX_979.xls) – 1 file
Radiographs (XXXX_979_Y.dcm) - 1 or more files
Coupon Testing (ALC-41000021-N-NNA.xls) – 2 (Fatigue, All Others) files
Microstructure (TRSNN-YYY-NNX.jpg or .png) – 1 or more files

Builds 2-6 – Same Information

Builds 7-12

Feedstock – 1 files
Print – LIMS Times Series – 1 files
Thermal Processing – 2 (Stress Relief and Anneal) files
Radiographic Inspection Guide – 1 files
Radiographs - 1 or more files
Coupon Testing – 2 (Fatigue, All Others) files
Microstructure – 1 or more files

L-PBF Machines Used

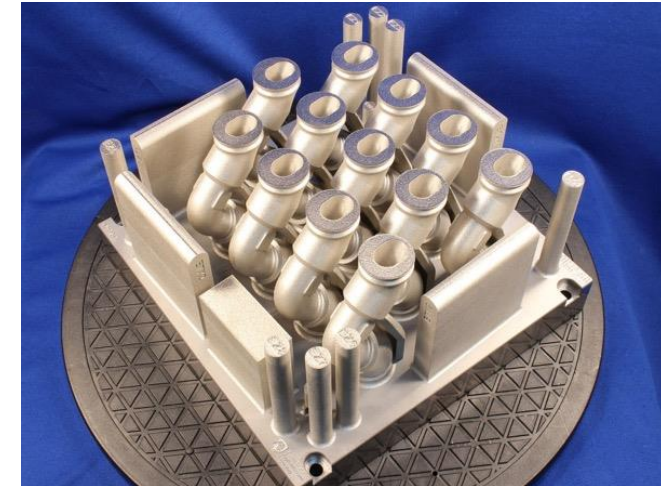
- ATI – M290 & M2
- Penn United – M290 – 2 S/Ns
- Innovative 3D Manufacturing – AM400 – 2 S/Ns

General Scope of Build Data



12 Total Builds in 316L per Supplier

- Build 1 - Replicate PSU-ARL Layout (12 Fuel Elbows and Multiple Coupons) – HIP Only
- Builds 2 & 3 – HIP Only
 - Production Representative Builds to Supplier's Design
 - Maximum Elbows and 4 Z-Tensile
- Builds 4 Through 6 – HIP Only
 - Simulated AMS 7032 Operational Qualification
 - Generate Data for AMS-7036, so 2 Powder Lots That Meet AMS-7037 Draft
- Builds 7 to 12 – Stress Relieve and Solution Anneal
 - Generate Data for AMS-7039, so 2 Powder Lots That Meet AMS-7037 Draft
 - Controlled Changes (2nd Machine, Parameter Change, Simulated Malfunction, Advice from Machine Learning Analyst) to Provide Data Set for Future Data Analytics / Machine Learning



Other Processes

- All Elbows and Coupons to Receive Digital Radiography
- All Elbows to Receive Tumble Deburr
- Elbows from Builds 3, 7, and 10 Will Also Receive Abrasive Flow Machining, Final Machining, Penetrant Inspection, and Passivation



Testing

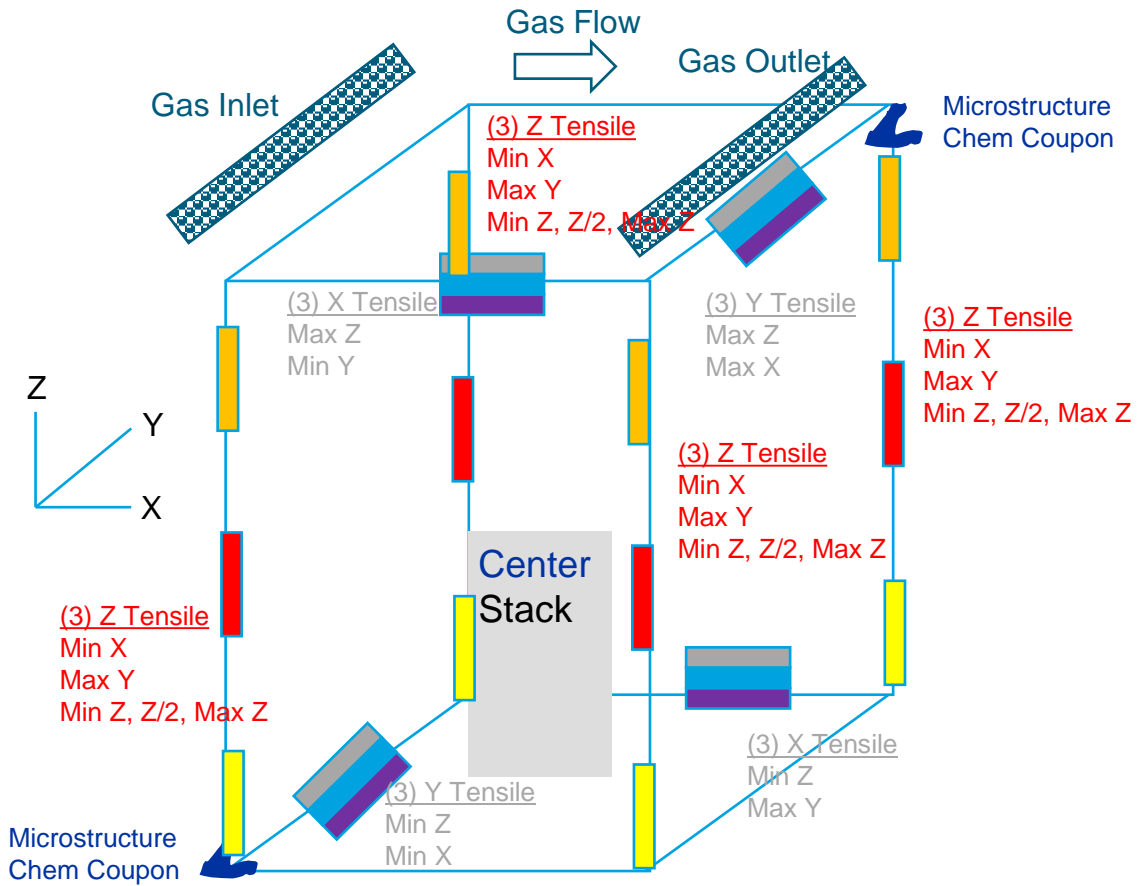
- Approximately 600 tensile tests across all suppliers, builds, and directions.
- Approximately 100 fatigue tests across all suppliers, builds, and directions.
- Chemistry, metallography, and density on all builds.

Baseline Build and Part Plan



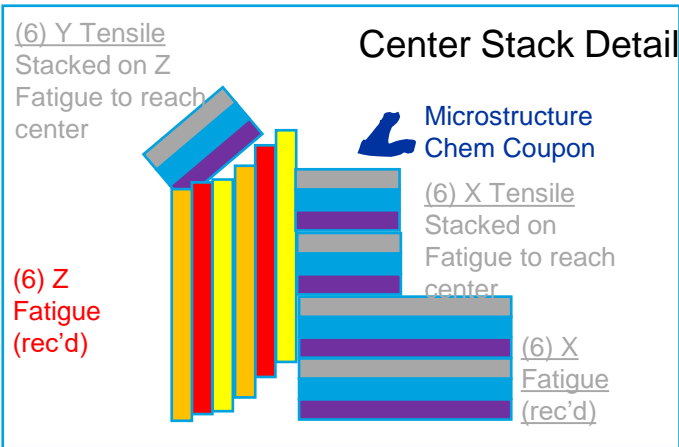
Build	Description	Powder Lot	Build Height	Powder Melted (cm ³)	Elbows	Rough Number of Test Coupons
1	PSU-ARL	A	110mm	1500	12	66 in ~12 Larger Pieces
2	Production Representative	A	110mm	1100	>12, plus Artifact	12
3		A				12
4	Simulated Operational Qualification	A	Supplier Desired Volume to Qualify	1000	0	78
5		A or B				78
6		B				78
7	Production Representative Two builds with slight changes	A	110mm	1100	>12, plus Artifact	12
8		A				12
9		A				12
10		A				12
11		B				12
12		B				12
13	Builds influenced during Phase 2	B				12
14		B				12

General Configuration of Builds 4-6



- 36 total tensile coupons printed of which 30 need to be tested
 - X – Print 12, Test 10
 - Y – Print 12, Test 10
 - Z – Print 12, Test 10
- 3 Total Microstructure
- Higher Z-Tensiles may be printed as towers with area of interest excised out
- High X-Tensiles and Y-Tensiles may be tops of vertical plates or utilize some form of support

Note: Flat coupons not shown



Selection Criteria to Enter Phase 1



- Need to Cover in Proposal and Presentation
- Tools and Software to Use
 - Uniqueness – 15%
 - Description Details – 15%
- Data They Plan to Use (More is Better) – 10%
- What They Plan to Demonstrate – 30%
 - Correlation of Input Parameters and Material Properties
 - Identification of Process Anomalies
- Benefit They Could Provide for Final 2 Builds (e.g. Optimization, Transfer to New Machine, etc.) – 30%

Categories and Scoring

Category	1 Point	2 Points	3 Points	4 Points	5 Points
Analyzed Data Types	1 Type	2 Types	3 Types	4 Types	All (Feedstock, Print, Thermal, Radiography, Coupon)
Analyzed Data Quantities	>10% of Builds	>20% of Builds	>40% of Builds	>60% of Builds	>80% of Builds
Made Meaningful Correlations	2 or more KPVs and outcomes		3 or more KPVs and outcomes		4 or more KPVs and outcomes
Insights Provided	Suggestion for Further Study		High Credible Suggestion		No Brainer to Adopt

Cost Share Awarded (Average Across Evaluation Team) – May be Applied to 1 Year of Membership

- <5 Points – \$0k
- 5-7 Points - \$15k
- >7 and <9 Points - \$30k
- >10 Points - \$45k

Q&A

Important Links:

- RFP Website: https://www.americamakes.us/project_calls/amnow-metals-challenge-project-call-feb-2022/
- For Additional Information on the AMNOW Program and/or to Register as a Supplier on the AMNOW AMIP Platform: <https://www.myamnow.com>